Available at www.ijcasonline.com ISSN 2349 – 0594

International Journal of Modern Chemistry and Applied Science

International Journal of Modern Chemistry and Applied Science 2015, 2(3),174-180

Analytical Study on Geometrical Features of Under-Reamed Pile by *Ansys*

Parikshith Shetty[1],Naveen B S[2], Naveen Kumar B S[3]

[1]*Structural Engineer Frames Group of Energy system,Pune,Maharashtra,India*
Email:parikshithshetty@yahoo.com
[2]*Assistant Professor Dept. of Civil RK University,Rajkot,Gujarat,India*
Email:bilichod.naveen@gmail.com
[3]*Assistant professor Dept. of civil Engineering, Ambo University, Ambo, Oramia, Ethiopia*
Email:naveensoppy@gmail.com

Abstract: The studies on under-reamed piles, most of them are done on the experimental side only, while theoretical studies, using the Finite Element Method, have been mostly confined to straight shafted (prismatic) piles. In a study with emphasis on the geometrical features of the under-reamed piles, no other method is as versatile as the Finite Element Method. The present investigation makes use of the finite element analysis for the under-reamed pile problem with special reference to its geometrical features, using the advanced software package ANSYS. The content of this project is limited to 2-D axisymmetric nonlinear analysis for axial compression, in layered soil, with respect to the geometrical parameters which include the number, size, location of the bulb, length, and diameter of pile stem. The pile is treated as linear, the soil and the pile-soil interface are treated as nonlinear. The project includes the study on under-reamed pile, in different cases with respect to various changes in geometric properties of the pile. We consider the soil as layered soil. The characteristics of layered soil such as friction coefficient, cohesion of soil and density of soil as constant are considered. Geometric property of pile is taken into consideration and taking diameter as variable with respect to constant length and ratio of diameter of bulb to diameter of stem. Then taking length as variable with respect to constant diameter and ratio of diameter of bulb to diameter of stem.then taking diameter of bulb varies with respect to constant length and diameter. Similarly taking bucket length as variable with respect to constant length diameter and ratio of diameter of bulb to diameter of stem. The comparison between single under-reamed pile and double under-reamed pile is also carried out.

Index Terms- Under reamed pile, load carrying capacity, pile foundations, FEM analysis, bulb diameter etc.

1. Introduction

Under-reamed piles are of bored cast in situ and bored compaction concrete types having one or more bulbs formed by suitably enlarging the borehole for the pile stem. With the provision of bulb, substantial bearing or anchorage is available. These piles find application in widely varying situations in different types of soils where foundations are required to be taken down to a certain depth in view of considerations like the need (a) to avoid the undesirable effect of seasonal moisture changes as in expansive soils (b) to reach firm strata (c) to obtain adequate capacity for downward, upward and lateral loads and moments or (d) to take the foundations below scour level. 0.3 When the ground consists of expansive soil, for example black cotton soil, the bulb of the under-reamed pile provides anchorage against uplift due to swelling pressure -apart from the increased bearing. In case, of filled-up or otherwise weak strata overlying.The firm strata, enlarged base in that form of under- reamed bulb in firm strata provides larger bearing area and piles of greater bearing capacity can be made. In loose to medium pervious sandy and silt strata, bored compaction piles can be used as the process of compaction increases the load bearing capacity of the piles.Under-reamed piles may also be used under situations where the vibration and noise caused during construction of piles are to be avoided. The provision of bulb is of special advantage in under-reamed piles to resist uplift and they can be used as anchors.[1]

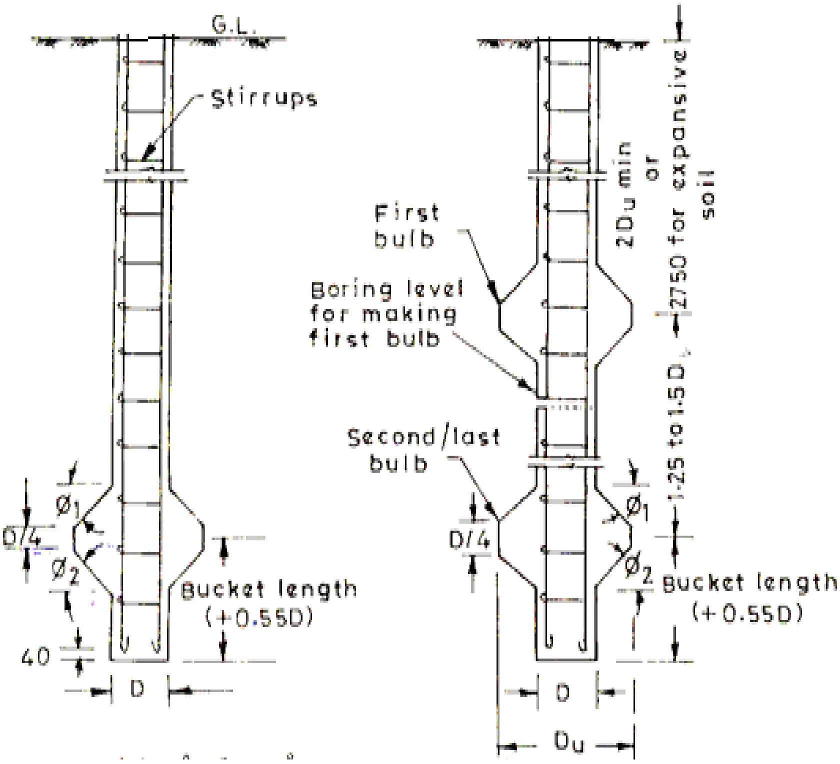
The load carrying capacity of under-reamed pile depends mainly on the pile dimensions and soil strata. Axial load on a pile is transmitted by point bearing at the toe and the projected area of the bulb and skin friction along the pile stem. Depending upon the nature of soil and pile geometry, in addition to the skin friction on stem, friction can develop on the soil cylinder between the extreme bulbs. In under-reamed compaction piles, the mechanism of load transfer remains the same but soil properties improved by compaction process are considered. In uplift load, point bearing component at toe is absent but unlike other straight shaft piles, point bearing on an annular projection of the bulb is present.

2. Design Considerations

Under-reamed pile foundations shall be designed in such a way that the load from the structure they support, can be transmitted to the soil without causing any soil failure and without causing such settlement, differential or total, under permanent transient loading as may result in structural damage and/or functional distress. The pile shaft should have adequate structural capacity to withstand all loads (vertical, axial or otherwise) and moments which are to be transmitted to the subsoil.[1]

In deep deposits of expansive soils the minimum length of piles, irrespective of any other considerations, shall be 3.5 m below ground level. If the expansive, soil deposits are of shallow depth and overlying non-expansive soil strata of good bearing or rock, piles of smaller length can also be provided. In recently filled up grounds or other strata or poor bearing, the piles should pass through them and rest in good bearing strata. The diameter of under-reamed bulbs may vary from 2 to 3 times stem diameter depending upon the feasibility of construction and design requirements. In bored cast in situ under-reamed piles the bulb diameter shall normally be 2.5 times, and in under-reamed compaction piles two times. For piles up to 30 cm diameter, the spacing of bulbs should not exceed 1.5 times the diameter of bulb. For piles of diameter greater than 30 cm spacing can be reduced to I.25 times the stem diameter.

The top-most bulb should be at a minimum depth of 2 times the bulb diameter. In expansive soils it should also not be less than l.75m below ground level. The minimum clearance below the underside of pile cap embedded in the ground and the bulb should be a minimum 1.5 times the bulb diameter. Under-reamed piles with more than two bulbs are not advisable without ensuring their feasibility in strata needing stabilization of boreholes by drilling mud. The number of bulbs in case of bored compaction piles should not exceed two in such strata. The minimum diameter of stem for borehole needing stabilization by drilling mud should be 25cm. The minimum diameter of stem for strata consisting of harmful constituents, such as sulphates, should be 30cm.[2]



TYPICAL DETAILS OF BORED CAST IN SITU UNDER-REAMEDPILE FOUNDATIONS

LOAD CARRYING CAPACITY FROM SOIL PROPERTIES

Clayey soils :

$$Q_u = A_p.N_c C_p + A_a.N_c.C'_a + C_a'.A_s' + \alpha.C_a.A_s$$

Where Qu = ultimate bearing capacity of pile
Ap = cross-sectional area of pile stem at toe leve
Nc = bearing capacity factor, usually taken as 9
Cp = cohesion of the soil around toe

Aa = π/4 (Du^2-D^2) where Du and D are the under reamed bulb and stem diameter respectively
C'a = average cohesion of soil around the under-reamed bulbs
A's = surface area of the cylinder circumscribing the under-reamed bulbs
α = reduction factor (usually 0.5 for clays)
Ca = average cohesion of the soil along the pile stem and
As = surface area of the stem.

3. Modeling and Analysis

In the current study, ANSYS nonlinear software is utilized to create 2D axisymmetric models and carry out all analysis. The software is able to perform the nonlinear analysis of under reamed pile under static loading, taking into account of both linear and nonlinear property of the pile and soil respectively. Contact analysis is done by interfacing between pile and soil media. The analysis and design of the under reamed pile is carried out using ANSYS computer program. The following topics describe some of the important areas in the modeling.

Control Model

A control model of under reamed pile is prepared as per the code specification for the following data

Length: 3.50m

Diameter of the stem: 0.30m

Ratio of bulb to stem: 2.50m

Bucket length: 0.55m

Modeling Of an Under Reamedpile

The material properties may be de fined as isotropic, orthotropic or anisotropic. However, the properties are actually utilized depends on the element type. For each element type, the materials are referenced indirectly through the section properties appropriate for that element type. For each material, we have to specify density (ρ), Young’s modulus (E), Poison’s ratio (μ).

The 2-D axisymmetric model is modeled as per the control model dimensions. The pile and soil is then meshed using plane 42 element, the contact pair is created using element Target169 and cont172. The meshed model is shown in the figure 2. The meshed model consists of elements and nodes.

Specifying material properties

The finite element model considered to consists of concrete and soil material. Each type of material requires certain type of material properties. The material properties are given in the table below.

Boundary Conditions

For the present study soil media is made finite since it is infinite material. By trial and error method infinite soil media can be converted into finite media and depending on this media vertical boundary parallel to the pile which is 5 times of diameter of the bulb is fixed in one direction. And also the horizontal boundary perpendicular to the pile which is 4 times of diameter of the bulb is fixed in two directions.

Material		Cohesion kPa	Friction angel	Density kN/m^3
soil	layer 1	55	18	18
	layer 2	50	20	18
	layer 3	45	22	19
Material		Young’s modulus kPa	Poison’s ratio	Density kN/m^3
Concrete		$2.5*10^7$	0.15	25

Analysis of under reamed pile

Contact analysis:

One of the biggest changes in structural Finite Element Analysis over the past years has been the addition of generalized contact algorithms to several codes. These tools allow analysts to model assembly structures quickly and accurately with a minimal amount of effort. With three different types of contact (point-point, point-surface, surface-surface) and several algorithms in each method, ANSYS has a wide variety of options for modeling interaction between objects. Contact problems fall into two general classes rigid-to-flexible and flexible-to-flexible. In rigid-to-flexible contact problems, one or more of the contacting surfaces are treated as rigid (i.e., it has a much higher stiffness relative to the deformable body it contacts). In general, any time a soft material comes in contact with a hard material, the problem may be assumed to be rigid-to-flexible. Many metal forming problems fall into this category. The other class, flexible-to-flexible, is the more common type. In this case, both (or all) contacting bodies are deformable (i.e., have similar stiffness’s ANSYS supports both rigid-to-flexible and flexible-to-flexible surface-to-surface contact elements. These contact elements use a "target surface" and a "contact surface" to form a contact pair. The target surface is modeled with either TARGE169 or TARGE170 (for 2-D and 3-D, respectively).The contact surface is modeled with elements CONTA171, CONTA172, CONTA173, and CONTA174.To create a contact pair, assign the same real constant number to both the target and contact elements.

Validation

Validation is done by comparing the ANSYS results to test report of routine pile load test for proposed construction of hostel block for Central Village pottery Institute at Khanapu.

Table1.2: Table displaying soil parameters of collected samples from bore holes

Name of proposed structures : Hostel block							
Bore hole identification with exact location: BH-1 at front side				**BH-2 at rear side**			
1	Depths of SPT conducted(m) & UDS sample collected	2.10 E8	3.20 O7	4.50 M6	1.50 I8	3.00 E15	4.50 M14
2	N – values observed	12	13	35	21	18	35
3	Density (kN/m^3)	16.7	17.0	19.7	18.0	17.6	19.6
4	Co eff. Of resistance C= Kg/cm^2	0.40	0.30	0.20	0.450	0.280	0.20
5	Angle of Shear Φ	24^0	26^0	36^0	27^0	25^0	38^0
6	**Wet Sieve Analysis:** a) Gravel (%) b) Sand (%) c) Silt & Clay (%)	8.40 21.50 70.10	12.30 33.40 54.30	18.50 30.90 50.60	6.90 28.20 64.90	10.65 32.85 56.50	17.75 34.20 48.05
7	**Atterberg Limits:** a) Liquid Limit (%) b) Plastic Limit (%) c) Plasticity Index (%)	38.00 30.50 7.50	36.00 29.20 6.80	33.50 27.80 5.70	40.00 29.60 10.40	36.50 29.00 7.50	34.00 27.50 6.50

Comparison of result of ANSYS and test report of routine pile load test for proposed construction of hostel block for Central Village pottery Institute at Khanapur is given below

Table1.3: Comparison of result of ANSYS and test report of routine pile

Sl. No.	Pile details	Applied Load (kN)	Practical Settlement(mm)	Software Settlement(mm)
1	Type: Under reamed Dia : 300mm Length: 4.30mt from GL Bulb : Single of 1.0m	340	12.50	12.269
2	Type: Under reamed Dia : 300mm Length: 5.5mt from GL Bulb : Single of 0.75m	320	14.91	20.230
3	Type: Under reamed Dia : 300mm Length: 6.0mt from GL Bulb : Single of 0.75m	325	15.82	20.801
4	Type: Under reamed Dia : 400mm Length: 5.5mt from GL Bulb : Single of 1.1m	425	14.86	16.797
5	Type: Under reamed Dia : 400mm Length: 5.0mt from GL Bulb : Single of 1.0m	425	15.20	16.914

Design data considered for all the buildings

Length and diameter of the under reamed pile

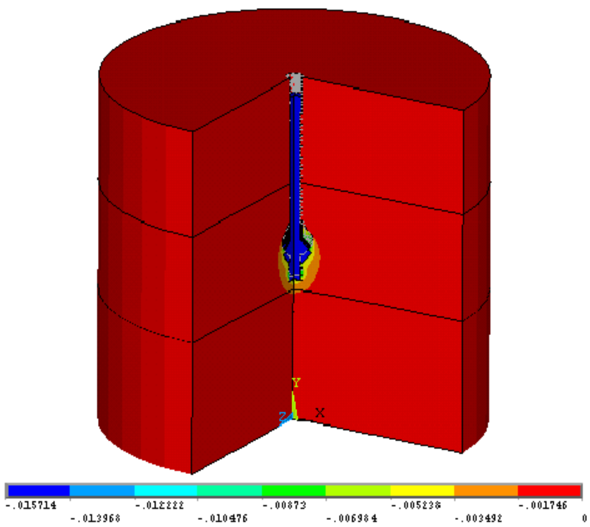
In this study a bulb of diameter 0.75m is provided on the stem at standard height from the tip whose length is made to vary. The results from the analysis are entered in table 4 which show that ultimate load in is generally insensitive to change in length.

A pile of length 3.5m has been used for these studies, with the diameter of the pile as the parameter. The results from the analysis are presented in table 5.It is seen that the increase in the ultimate load carrying capacity with increase diameter

Table1.4: Load carrying capacity with varying length of pile (L): 3.5-6m Load carrying capacity with varying Diameter of pile stems (D): 200-500mm

Sl. No	Pile details	Load in compression (kN)	Settlement(mm)
1	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m	270	15.744
2	Dia : 300mm Length: 4.00m from GL Bulb : Single of 0.75m	270	14.351
3	Dia : 300mm Length: 5.00m from GL Bulb : Single of 0.75m	280	15.948
4	Dia : 300mm Length: 6.00m from GL Bulb : Single of 0.75m	285	15.325

Sl. No	Pile details	Load in compression (kN)	Settlement(mm)
1	Dia : 200mm Length: 3.50m from GL Bulb : Single of 0.50m	150	14.423
2	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m	270	15.744
3	Dia : 400mm Length: 3.50m from GL Bulb : Single of 1.00m	420	14.618
4	Dia : 500mm Length: 3.50m from GL Bulb : Single of 1.25m	560	14.930



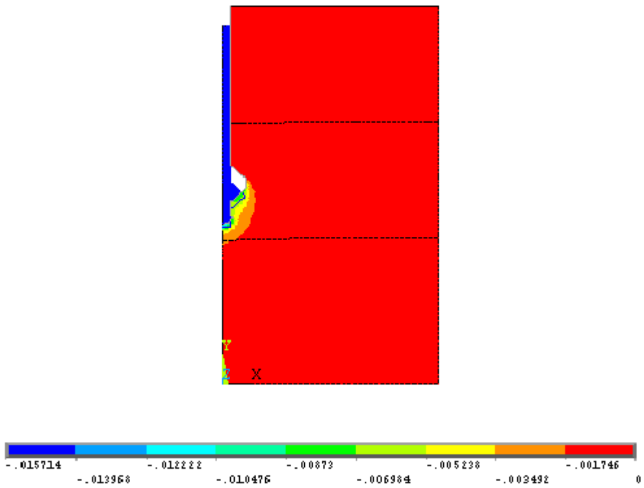
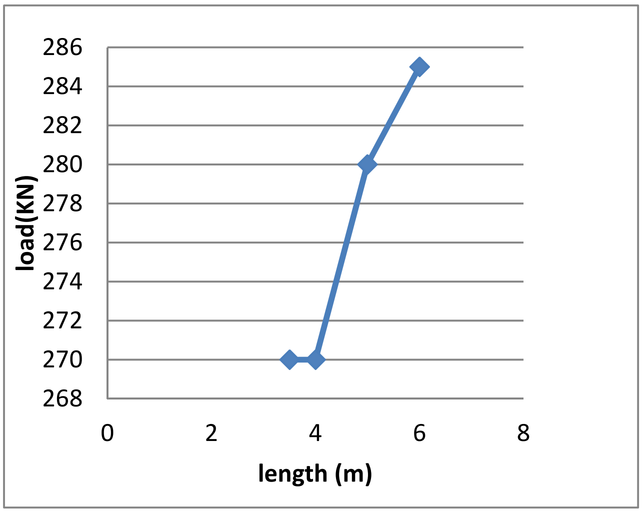
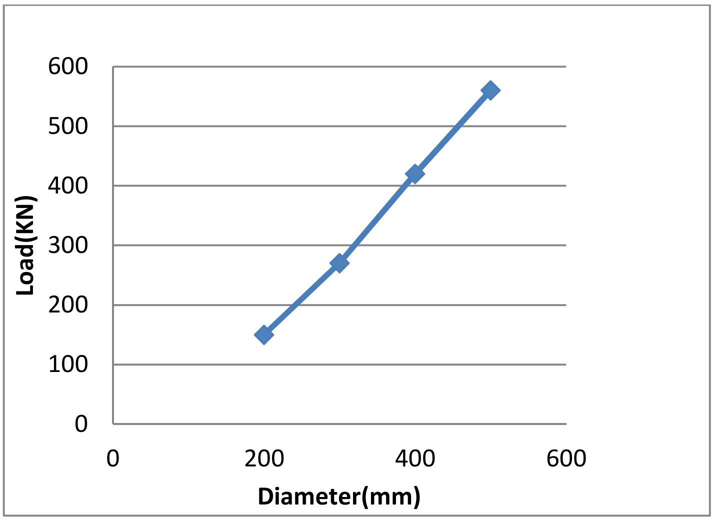


Fig1.1: Ansys Soil model showing Y displacement of Under-reamed pile



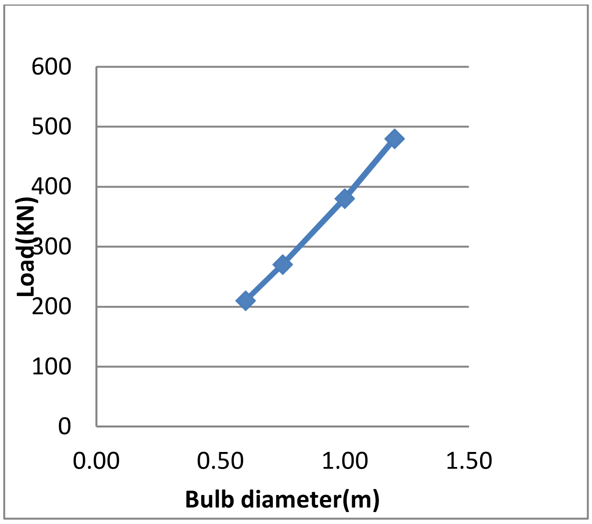


Graph 1.1:Graph of variation of length of pile vs loadGraph of variation of diameter of pile vs load

Diameter of Bulb (Du)

In this, keeping the length of the pile as 3.5m, with diameter 0.3m, the diameter under ream is varied from 0.6 to 1.2m. It is of interest to know the gain in the ultimate load against the corresponding increase in material input when under reams of increasing diameter are considered. These results are presented in table 6. The gain in strength is marked if larger bulbs did not pose problems as regards stability and retention of the enlarged excavation in construction.

Sl. No	Pile details	Load in compression (kN)	Settlement (mm)
1	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.60m	210	15.725
2	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m	270	15.744
3	Dia : 300mm Length: 3.50m from GL Bulb : Single of 1.00m	380	14.449
4	Dia : 300mm Length: 3.50m from GL Bulb : Single of 1.20m	480	14.766



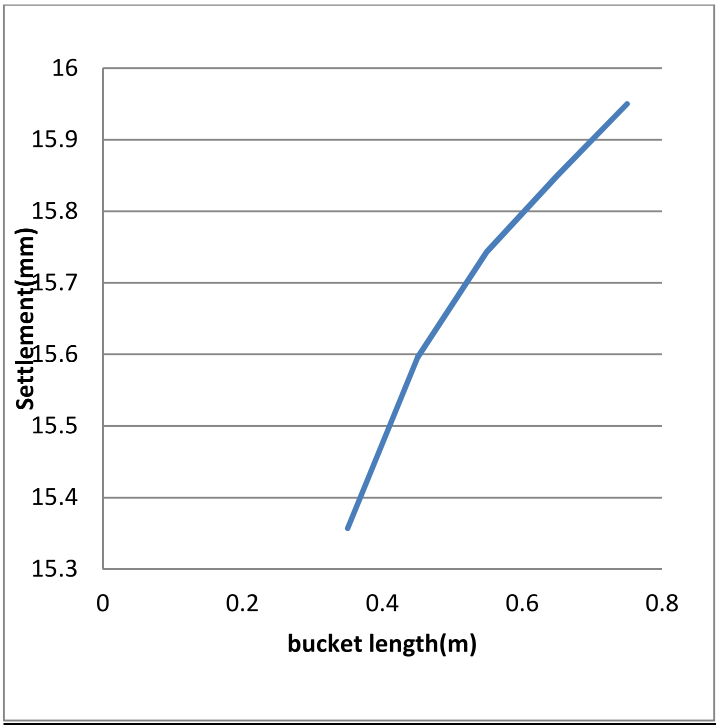
Load carrying capacity with varying Diameter of bulb (Du) : 0.60-1.2mGraph of variation of under reamed bulb diameter of pile vs load

Bucket Length (Lb)

A pile length 3.5m but with standard values of 0.3 and 0.75m respectively for diameter of the pile and diameter of the bulb, has been used for these studies, with the height of center of the bulb from the bottom of pile as the parameter. The results pertaining to the location of the bulb on the stem are given in table 7

It is to be pointed out in this connection that in the manual method of construction of under reamed piles, illustrated by Kurian (1992), a length of the stem projects below the bulb, which corresponding to the space occupied by the bucket which receives the soil scraped out from the enlarged part of excavation forming the bulb. Such a projection can however be avoided if one resorts to more mechanized methods of construction as practiced in west

Sl. No	Pile details	Load in compression (kN)	Settlement (mm)
1	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m Bucket length :0.35m	270	15.357
2	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m Bucket length :0.45	270	15.595
3	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m Bucket length :0.55	270	15.744
4	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m Bucket length :0.65	270	15.850
5	Dia : 300mm Length: 3.50m from GL Bulb : Single of 0.75m Bucket length :0.75	270	15.950



Load carrying capacity with varying Bucket length (Lb) : 0.35-0.75Graph of variation of bucket length of under reamed of pile vs settlement

4. Conclusions

The conclusions drawn from the above studies have been stated below in a quantitative form to the extent possible. At any rate, they are indicative of the general trend of the results.

1. An advanced package ANSYS with excellent pre- and post- processing features, can yield a vast number of results from each analysis, unlike experimental results.
2. For given soil and pile, the influence of location of the bulb is not significant beyond the standard height 0.55m (applying to D 0.30m) from the base of pile for the location of the under-ream. However this capacity is lesser compared to the case of the under-ream located at the bottom.

3. As regards the diameter of the pile stem, there is an increase in load carrying capacity by 373.33% when the diameter of the pile stem varies from 0.20 to 0.50m.
4. In case of diameter of the bulb, there is an increase in load carrying capacity by 228.57% when the diameter of the pile stem varies from 0.60 to 1.20m. However large under-reams disproportionate to the stem cannot be attempted as they pose difficulty in construction, with regard to keeping the under-ream cavity stable.
5. For given soil as the length of the pile increases from 3.5 to 6m there is a 1.055% increase in the load carrying capacity of the pile. It shows that ultimate load is generally insensitive.

Further Scope

The problem related to under reamed pile can be further studied for the following consideration.

- The study may further carry out by doing 3D model of the pile grope, capacity can be found. And also lateral load behavior of pile can found.
- Further study may be under taken considering soil structure interaction.

5.References

1. IS 2911(part 3) – 1980 “Code of practice for design and construction of pile foundations” (First Revision), BIS, New Delhi.
2. Ultimate Bearing Capacity of Underreamed Pile – Finite Element Approach by Neha Shrivastava Dept. of Civil Engineering, Jaypee Institute of Engineering and Technology, Guna (M. P.), India.
3. Settlement and load distribution analysis of Under reamed piles C. Y. Lee Department of Civil Engineering, College of Engineering, University Tenaga Nasional, Selangor, Malaysia.
4. Contribution to the Efficiency of the Underreamed Piles in the Clay by B. Soldo, K. Ivandić, T. Koprek University of Zagreb, Faculty of Geotechnical Engineering, Croatia.
5. Dr. B. C. Punmia, Ashok Kumar jain and Arun Kumar jain “Soil Mechanics and Foundations” 16th edition, Laxmi Publications Pvt. Ltd.
6. Swami Saran “Analysis and Design of Substructures” second edition, Oxford and IBH Publication New Delhi.
7. A. R. K. Swamy and R. Suresh Kumar “Modeling and Finite Element Analysis”.
8. C. S. Krishnamoorthy “Finite Element Analysis” second edition, McGraw-Hill Companies, New Delhi.
9. H. G. Poulos and E. H. Davis “Pile Foundation Analysis and Design”.
10. Joseph E. Bowles “Foundation Analysis and Design” fifth edition, McGraw-Hill Companies, New Delhi.